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THE IMPACT OF A FISH FARM ON A BOTTLENOSE DOLPHIN POPULATION IN THE MEDITERRANEAN SEA

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ABSTRACT

The increasing presence of aquaculture in coastal waters calls for a better understanding of its environmental effects. Despite a number of studies focusing on the impact of aquaculture on marine mammals, the interaction between common bottlenose dolphins (*Tursiops truncatus*) with fish farms has been the subject of few investigations (Watson-Capps and Mann, 2005). In this paper we report the results of our research on the interaction between bottlenose dolphins with a fish farm on the Sardinian coast (Italy) from 1991 to 2004. We divided the study area latitudinally into two sections: southern (Gulf of Olbia) and northern (Gulf of Congianus). In the southern section in November 1995 the plant of a small fish farm was completely increased and transformed. Data were pooled into two periods (1991 to 1994 and 1999 to 2004). All years but 2003 were sampled. During the first and second research periods the same land-based searches were conducted under fair to excellent weather conditions. A total of 255 sightings were carried out in over 1320 hours of research of dolphins: in the first period 52 sightings were recorded in 517 hours of research, in the second period 203 sightings were realized in 803 hours of research. The presence of bottlenose dolphins changed dramatically between the two research periods. Observations of dolphins indicate that are mainly present in the southern area during the second period. The preference for the southern section seemed to be consistent after the transformation of the fish farm, since 1995.

INTRODUCTION

Aquaculture, the farming of finfish or shellfish, has grown 11% in the last decade, becoming the fastest growing industry in the world food economy (Newton, 2000). Most of the literature to date has focused on pinnipeds that prey on finfish and some shellfish, but there is a paudity of information on cetaceans and aquaculture (Wursig and Gailey, 2002; Kemper et al., 2003; Watson-Capps and Mann, 2005). Unlike pinnipeds, cetaceans have not been reported to consume fish or shellfish out of farms, but have been known to get entangled in equipment, resulting in the

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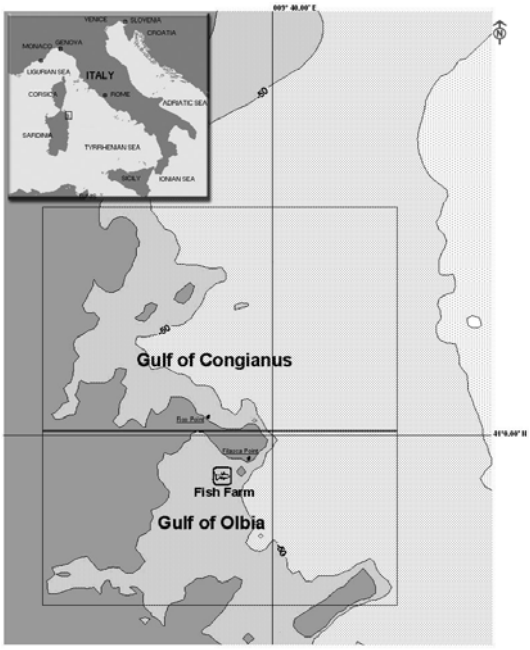

Figure 1.
Study area and land watch study sites

damage of gear, release of fish, and self injury (Dans et al., 1997; Kemper and Gibbs, 2001; Crespo and Hall, 2002; Hall and Donovan, 2002).

Common bottlenose dolphins (*Tursiops truncatus*) are appropriate and useful study animals in this case because of their world-wide distribution in tropical and temperate coastal waters (Leatherwood and Reeves, 1983). Because of their cosmopolitan distribution, the information gained in our study can be applied to management of fin fish farms world wide and, because they share valuable coastal habitats with humans, bottlenose dolphins may be particularly affected by aquaculture. Previous work on the north-eastern Sardinia bottlenose dolphin population has shown a degree of residency of recognised animals and highlighted their abundance on the study area (Marini, 1995; Díaz López, 2002; Díaz López et al., 2002). In this study, we report a clear change in the spatial and temporary distribution of the bottlenose dolphins on the north-eastern coast of Sardinia caused by the presence and transformation of a fish farm.

Even though these data are from only one bottlenose dolphin study site, it is appropriate to extrapolate to other areas. Comparisons of the North eastern coast of Sardinia to other sites show similar bottlenose dolphin social structure (Díaz López et al., 2001, 2002). Therefore, our study offers the best available test to date of the effects of a fish farm on small cetacean ranging

MATERIALS AND METHODS

Study area

Our study focuses in the Gulf of Olbia and Gulf of Congianus, on the North eastern coast of Sardinia (Italy). The study area includes about 80 square nautical miles of waters with a depth up to 100 meters with large and small islands and a complex shoreline (Figure 1).

We divided the study area latitudinally into two sections (southern and northern). The southern section (Gulf of Olbia) extended from Cape of Ceraso (40º 55.258'N) to Gulf of Aranci (41º 00.162'N). The northern section (Gulf of Congianus) extended from 41º 04.762' to 41º00.351'N.

Recent history of fish farms in Golfo Aranci

In the area in October 1992 a small fish farm, with bass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus auratus*), has been built up, it covered 0.6 ha. and contained 174 tons of ichthyic biomass. In November 1995 the plant of the fish farm was completely increased and transformed, until now it covers 2.4 ha. and contains 900 tons of ichthyic biomass. The floating cages were constructed on nylon mesh netting. There was not any change in location of the fish farm between 1992 and 2004.

Data collection

Data were pooled over two periods. Period one: before the fish farm transformation in 1995 (1991 to 1994) and Period two: after this change (1999 to 2004). All years but 2003 were sampled.

The same methodologies have been adopted in the two research periods, where the results that were recorded in the different periods are really comparable. Spotting and observation of the animals have been carried out with naked eye and binoculars.

Observations were made by experienced researchers. A dolphin "sighting" was defined as a

Table 1.
Observed frequency of sightings

	Number of sightings	Research Effort[a]	Index of presence[b]
Period 1991 – 1994	52**	517 h	0,10
Period 1999 – 2005	203	803 h	0,25
Total of research	255	1320 h	0,19

[a] Time spent in the field searching the dolphins, excluding the sighting time; [b] The observed frequency of sightings (number of sightings per research effort); **Chi Square ($\div^2$)= 32.64, P value < 0.001.

group of dolphins usually involved in the same activity (termed focal group, Shane, 1990). Sightings wereconsidered satisfying when the visibility was not reduced by rain or fog and sea conditions were equal or below 3 of the Douglas scale. For each group we recorded on an audio tape: date, start and end time, size group and number of bottlenose dolphin adults and calves. The encounter continued until the group was lost (a group was considered lost after 15 minutes without a sighting).

Observations were made during daylight hours between 0700 and 1900h. Opportunistic video recordings were also made to document and verify size group, presence of immatures and behavioural interaction. Recorded data were transcribed on the evening of the observations.

Search procedure

Land based observations of cetaceans provide the opportunity to collect data over a wide area without the risk of observer interference. Two shore watches were used in this study to record habitat use and movements of dolphins during the first and second period. It is possible to overview the Gulf of Congianus (Northern section) from the land-based point called Fico point, while the Gulf of Olbia (Southern section) with the fish farm, this latter in this section close to the shoreline and is observed from Filasca point.

Data analysis

The year was divided into seasons to assess differences in frequency of occurrence of the bottlenose dolphins in each location. Seasons were defined as follow:

Winter: December, January and February.

Spring: March, April and May.

Summer: June, July and August.

Autumn: September, October and November.

The observed frequency of sightings (number of sightings per research effort) was compared for different areas or periods using a Chi-square contingence table, to investigate the deviation of observed frequency of sightings from the expected frequency. We developed contingency tables to analyse if the distribution of bottlenose dolphins was homogeneous, then the chances of observing them in any area or period would be equal.

The evolution of the observed frequency of sightings over time (per seasons) was analysed using Spearman's rank-order correlation.

Bottlenose dolphin group size was compared for different areas or periods using a Mann-Whitney U-Test (Flower and Cohen, 1993). All statistics were performed with Past , statistics software (Hammer et al., 2001).

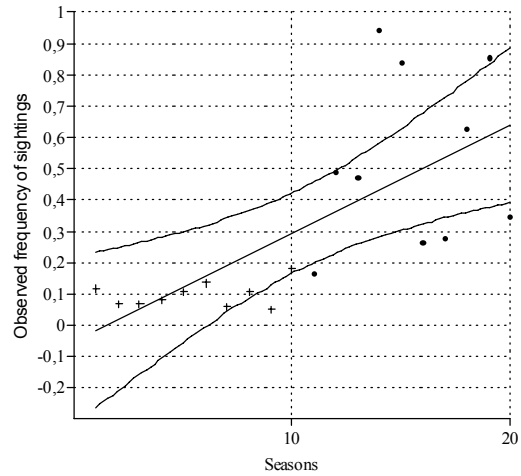

Figure 2.
The evolution of the observed frequency of sightings over time (per seasons).

RESULTS AND DISCUSSION

Effort and site fidelity

A total of 255 sightings were carried out in 1320 hours of research of dolphins: in the first period (1991-1994) 52 sightings were recorded in 517 hours of research, while in the second period (1999 - 2004) 203 sightings were realized in 803 hours of research (Table 1). Bottlenose dolphins were observed year round.

A high degree of temporary variation in presence was seen throughout the research between 1991 and 2004 ($P<0.001$, Spearman's $rs = 0.77$, $n= 20$, Figure 2). The presence of bottlenose dolphins changed dramatically between the two periods (Contingence table ?2 test, first period vs. second period $P<0.001$) showing a higher presence in the second period.

Sightings of bottlenose dolphins were not homogeneous throughout the study area (Table 2). In the spatial analyses the Chi-square value was contributed by differences from expected sighting frequency in the southern area (Gulf of Olbia) (Contingence table ?2 test, north vs. south $P<0.001$). Bottlenose dolphins tended to spend more time in this area than they would be expected if sightings were evenly distributed among areas.

During the first period sightings of bottlenose dolphins were not related to the shoreline along which they were observed (Contingence table ?2 test, north vs. south: $P>0.05$).

During the second period, the presence of bottlenose dolphins in the southern area showed a marked stratification of habitat use with more commonly sighted dolphins found consistently in the southern area (Contingence table ?2 test, north vs. south: $P<0.001$).

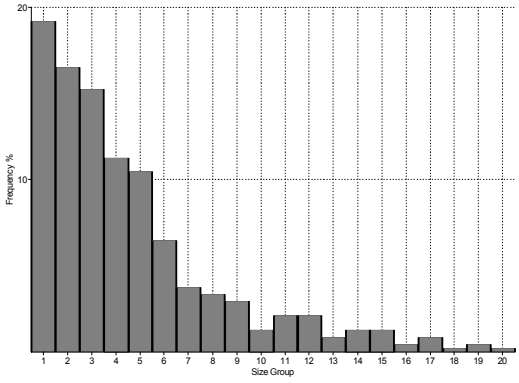

Figure 3.
Frequency distribution of group sizes.

The data from land watch surveys showed a median group size of 4.0 (Mean = 4.77, SD = 3.76, range = 1 - 20). Bottlenose dolphin group size was not related to the shoreline along which they were observed (north vs. south area: $U = 28$, $P>0.05$, Mann-Withney U-Test) and was not independent between periods (period 1 vs. period 2: $U = 47$, $P>0.05$, Mann-Withney U-Test). The majority of groups sighted were of < 4 animals but ranged from single animals to groups of 20 animals (Figure 3).

DISCUSSION

Predators of cultured stock may build up round marine farms, since they supply an abundant source of food. The bottlenose dolphins studied here appeared to have been attracted by aquaculture. This change may be induced by variations in the prey species

Table 2.
Changes in distribution of dolphins using the North eastern coast of Sardinia.

	1991 – 1994		1999 – 2005		Total of research	
	Sightings	Research Effort	Sightings	Research Effort	Sightings	Hours of research
Northern area[1]	12	141	59	439	71	580
Southern area[2]	40	376	144**	364	184^{++}	740

1-Gulf of Congianus; 2-Gulf of Olbia;
** Chi Square ($\div^2$)= 42.50, P value < 0.001, $^{++}$ Chi Square ($\div^2$)= 22.83, P value < 0.001.

distribution and abundance (ecological conditions) caused by the transformation and increasing of the fish farm. The transformation of this fish farm was the only drastic environmental change in the Gulf of Olbia from 1995 to 1999, while the other human activities (e.g. fishery activities, marine traffic, etc) did not change at all. Detailed sightings around the fish farm provided the strongest evidence that dolphins are attracted by fish farm.

Dolphins were observed to feed, around the fish cages in the fish farm, wild fishes attracted by the nourishment of the fish farm (Díaz López et al., 2001). The nourishment coming from the fish farm increased the presence of "wild" fishes in the surrounding area. The presence of the fish farm allows a concentration of food resource favouring bottlenose dolphin opportunistic nourishment. This trophic availability probably created a "sponge effect" for bottlenose dolphins groups originally not exploiting the area. There was a tendency for wild fish to aggregate near the fish farms and it is possible that elevated predation on wild fish stocks could occur due to this association. This adjustment to new environmental conditions reflects the well-known ecological plasticity of this species.

Groups averaging 1 - 20 individuals, usually composed of fewer than 10 animals and with the population typically spread into small units are reported as characteristic of coastal common bottlenose dolphin populations (Scott et al., 1990, Shane, 1990; Wilson, 1995; Bearzi & Politi, 1997).

Feeding preferences of bottlenose dolphins in the study area are not known. From studies in other areas, bottlenose dolphins are known to eat a wide variety of prey species, while mostly fishes and cephalopodos have been recorded in the diet in some areas (Blanco et al., 2003, Barros & Wells, 1998). Without a more detailed survey of the north eastern coast of Sardinia, for fish species and distribution, it is not possible to relate seasonality with prey dynamics.

The effects of aquaculture on the common bottlenose dolphin population may compete to existing anthropogenic pressures, such as boat traffic (Polo, et al., 2002). Future studies on cetaceans and aquaculture should collect baseline movement and behavioural data at least several years before the site is established to account for yearly and seasonal variation and to establish which habitats are critical for cetaceans.

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